Analysis on Optical Waveguide (Free Space Optics) via Beam Propagation Method (BPM)

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This report is submitted in partial fulfillment of the requirement for the award of Bachelor of Electronic Engineering (Wireless Communication) With Honors

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To my beloved family and friends

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ABSTRACT

This project presents the study and simulation of Free Space Optics (FSO) communication link and analysis of FSO system performance. Free Space Optics (FSO) also called Optical Wireless (OW) is regarded as high speed wireless communication technology due to the security and high data rates. FSO communication system involves the transmission of modulated optical signal through the atmosphere to obtain broadband communications. FSO systems can function over distances of several kilometers. As long as there is a clear line of sight between the source and the destination, and enough transmitter power, communication is theoretically possible. It offers an attractive alternative for transferring high-bandwidth data when fiber optic cable is neither practical nor feasible. However the performance of a FSO link is primarily dependent upon the atmospheric weather effects such as atmospheric attenuation, scintillation, window attenuation, alignment or building motion, solar interference and line-of-sight obstruction. OptiSystem and MATLAB are used as simulation tool to simulate the atmospheric weather effects. The result of simulation shows these effects attenuate the FSO signal as it travels through a certain distances.

ABSTRAK

Projek ini menyajikan kajian dan simulasi link Free Space Optics (FSO) komunikasi dan analisa prestasi sistem FSO. Free Space Optics (FSO) juga disebut Optical Wireless (OW) dianggap sebagai teknologi komunikasi wayarles kelajuan tinggi kerana keselamatan dan kelajuan data yang tinggi. Sistem komunikasi FSO melibatkan penghantaran isyarat optik termodulasi melalui atmosfera untuk mendapatkan komunikasi jalur lebar. Sistem FSO boleh berfungsi lebih dari jarak beberapa kilometer. Selama ada garis yang jelas kelihatan antara sumber dan tujuan, dan kekuatan pemancar yang cukup, komunikasi secara teoritis boleh berlaku. Ini menawarkan alternatif yang menarik untuk memindahkan data bandwidth tinggi ketika kabel fiber optik tidak praktikal. Namun prestasi link FSO adalah terutama bergantung pada kesan cuaca atmosfera seperti redaman atmosfera, kilau, redaman tetingkap, keselarasan atau gerakan bangunan, gangguan matahari dan halangan antara sumber dan tujuan. OptiSystem dan MATLAB digunakan sebagai alat simulasi untuk mensimulasi kesan cuaca atmosfera. Hasil daripada simulasi menujukkan bahawa kesan-kesan tersebut melemahkan isyarat FSO setelah ia berjalan ke satu jarak yang tertentu.

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BER	-	Bit error rates
FSO	-	Free Space Optics
IrDA	-	Infrared Data Association
LAN	-	Local Area Network
LED	-	Light-emitting diodes
P_t	-	Power transmit

LIST OF APPENDIX

CHAPTER I

INTRODUCTION

This chapter includes an introduction of Free Space Optics (FSO), project objectives, problem statement, and project scope, as well as brief explanation of methodology and report structure.

1.1 Introduction of FSO

Free-space optical (FSO) has been used for more than a decade as a short/medium distance point-to-point (building-to-building) connectivity solution. The license free nature of this technology combined with its high-speed bandwidth capabilities, comparable to optical fiber make it becomes the most promising high data rate communication technology. FSO communication involves the use of optical links across the space between two points, either within the Earth's atmosphere, or in outer space. The transmitter made up of optical source and telescope to direct the beam toward the receiver. The photo detector in the receiver processes the received optical signal. The optical links usually use laser light, although low-data-rate communication over short distances is possible using light-emitting diodes (LEDs). Infrared Data Association (IrDA) in most laptop/palmtop computer is a very simple form of free-space optical communications using LEDs.

Free-space optical communications has a number of applications, such as to become a last (or first) mile telecommunications link, as a LAN link between buildings, as a LAN link within a room using diffusive optic, for communications between spacecraft, including elements of a satellite constellation and for interstellar communication.

However there are a variety of deleterious features of the atmospheric channel that may lead to serious signal fading and even complete loss of signal. This results in increased system bit error rates (BERs). The primary factors affecting performance include atmospheric attenuation, scintillation, building motion, and physical obstructions. Several simulations using simulation tools are carried out to further investigate FSO system performance.

1.2 Objectives

The first objective of the project is to study and understand the performance of FSO communication system as a point to point wireless communication. This includes studying of how the system works and clarifying its advantages' and disadvantages in the daily application.

The second objective is to study the atmospheric weather effects on the propagation of optical beam in the waveguide (or FSO). These effects are rain attenuation, scattering effect, scintillation effect and atmospheric effect which limiting the maximum data rate of the system. Define the realistic performance limitations of FSO regard to atmospheric considerations is important.

The third objective is to perform simulation of FSO system under different weather conditions using OptiSystem and MATLAB to evaluate and predict pulse propagation in the atmosphere. The simulation is done in order to show the effect of transmission medium (atmosphere) to a signal along the propagation path and relate the outcome on the pulse behavior as well as the quality of the communication link.

1.3 Problem Statement

While fiber-optic cable and FSO technology share many of the same attributes, they face different challenges due to the way they transmit information. While fiber is subject to outside disturbances from wayward construction backhoes, and even sharks when deployed under sea, FSO technology is subject to its own potential outside disturbances.

Optical wireless networks based on FSO technology must be designed to combat changes in the atmosphere, which can affect FSO system performance capacity. And because FSO is a line-of-sight technology, the interconnecting points must be free from physical obstruction and able to "see" each other. Among the issues to be considered when deploying FSO-based optical wireless systems are fog which leads to absorption and scattering, scintillation, atmospheric turbulences, physical obstructions and building sway.

These effects degrade the quality of communication link and resulting of increasing BER. Therefore there exists the need for accurate channel characterization in order to understand and mitigate the problem.

1.4 Project Scope

A few guidelines are proposed so that this project is narrowed to a certain boundaries. This will ensure that this project achieves its objectives. First part of the project is focused on literature review and study of FSO communication system, the technology deployed, and the advantages and limitation of FSO as high bandwidth wireless communication technology.

The second part of the project is focused on the simulation of different atmospheric weather effects on FSO pulse propagation in the atmosphere. This project utilized OptiSystem to design the FSO communication link and MATLAB to simulate pulse propagation in the atmosphere for 3km distance. The signal attenuation is observed and analyzed from the result of simulation.

1.5 Brief Explanation of Methodology

Firstly all the information gathered for this project is through research via internet and library, the material includes journal paper, articles from books, thesis paper, and internet references.

OptiSystem and MATLAB software are introduced as simulation tool in this project. OptiSystem is used to design the FSO communication link while Matlab is used to simulate different atmospheric weather effects on FSO signal propagation.

1.6 Report Structure

First chapter of the report is about project introduction. FSO has been of interest in recent years due to the increase in demand for high data link speed, especially in urban area. However it suffers from adverse weather conditions such as fog and rain. Therefore the objective of the project is to study and simulate an accurate FSO model to show the weather effects on propagation of optical signal.

Second chapter covers the literature review of FSO system, the development of FSO communication, the technology used and also benefits and limitation of this emerging technology. Understanding on this chapter helps in the simulation in the chapter later.

Research methodology is explained detail in the third chapter. The chapter shows how the simulations tools are being utilized in doing the simulation. It includes the simulation specification.

Results from simulation are presented in the fourth chapter. Comparison and analysis are made regarding to the result obtained.

Conclusion of the entire project is made in chapter five and some recommendations are suggested for future study.

CHAPTER II

LITERATURE REVIEW

This chapter will describe details about Free Space Optics (FSO), literature review on the history of FSO, basic principles, how does FSO works, advantages and performance limitation of FSO.

2.1 What is Free Space Optics (FSO)

Free-Space Optics (FSO), also called Optical Wireless OW) is a line-of-sight technology that uses lasers to provide optical bandwidth connections. It refers to the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain broadband communications. FSO systems can function over distances of several kilometers. As long as there is a clear line of sight between the source and the destination and enough power transmitted, communication is theoretically possible.

Currently, FSO offers capacities in the range of 100Mbps to 2.5Gbps of data, voice and video communications through the air, allowing optical connectivity without requiring fiber-optic cable or securing spectrum licenses. These systems are compatible with a wide range of applications and markets since they are sufficiently flexible as to be easily implemented.

FSO requires light, which can be focused by using either light emitting diodes (LEDs) or lasers (light amplification by stimulated emission of radiation). The use of lasers is a simple concept similar to optical transmissions using fiber-optic cables; the only difference is the medium. Light travels through air faster than it does through glass, so it is fair to classify FSO as optical communications at the speed of light. FSO is all-optical without the labor of digging up sidewalk to install a fiber link and it requires no government licensing and can be readily deployed within hours of the availability of line-of-sight access. This means no hassles, no backlog, and no intermediary devices to the fiber backbone.

FSO technology is relatively simple. It's based on connectivity between FSO units, each consisting of an optical transceiver with a laser transmitter and a receiver to provide full duplex (bi-directional) capability. Each FSO unit uses a high-power optical source (i.e. laser), plus a lens that transmits light through the atmosphere to another lens receiving the information. The receiving lens connects to a high-sensitivity receiver via optical fiber. FSO technology requires no spectrum licensing. FSO is easily upgradeable, and its open interfaces support equipment from a variety of vendors, which helps service providers protect their investment in embedded telecommunications infrastructure.

2.2 History of Free Space Optics (FSO)

The engineering maturity of Free Space Optics (FSO) is often underestimated, due to a misunderstanding of how long Free Space Optics (FSO) systems have been under development. Historically, Free Space Optics (FSO) or optical wireless communications was first demonstrated by Alexander Graham Bell in the late nineteenth century (prior to his demonstration of the telephone!). Bell’s Free Space Optics (FSO) experiment converted voice sounds into telephone signals and transmitted them between receivers through free air space along a beam of light for a distance of some 600 feet. He named his experimental device the “photo phone,” as shown in Figure 2.1. Bell considered this optical technology – and not the telephone – his pre-eminent invention because it did not require wires for transmission [1].

Although Bell’s photo phone never became a commercial reality, it demonstrated the basic principle of optical communications. Essentially all of the engineering of today's Free Space Optics (FSO) or free space optical communications systems was done over the past 40 years or so, mostly for defense applications. By addressing the principal engineering challenges of Free Space Optics (FSO), this aerospace/defense activity established a strong foundation upon which today's commercial laser-based Free Space Optics (FSO) systems are based.

In the mid-1960's, the military and NASA initiated experiments to utilized the laser as a means of communication between the Goddard Space Flight Center and the Gemini-7 orbiting space capsule. FSO has been used for more than 30 years to provide fast communication links in remote locations. While fiber-optic communications has gained acceptance in the telecommunications industry, FSO communications is still relatively new. FSO technology enables bandwidth transmission capabilities that are similar to fiber optics, using similar optical transmitters and receivers and even enabling WDM-like technologies to operate through free space.

Figure 2.1: Historical photos of FSO

Figure 2.2: FSO transceiver device, old and new design

2.3 How Free Space Optics (FSO) Works?

FSO involves the optical transmission of voice, video, and data using air as the medium of transmission as opposed to fiber optic cable. FSO technology is relatively simple. It's based on connectivity between FSO-based optical wireless units, each consisting of an optical transceiver with a laser transmitter and a receiver to provide full-duplex (bi-directional) capability, as shown in Figure 2.3.

In order to transmit any information, network traffic is first converted into pulses of invisible light representing 1’s and 0’s with the presence or absence of pulses. Transmitter projects the carefully aimed light pulses into the air toward the receiver. A receiver at the other end of the link collects the light using lenses and/or mirrors. Received signal converted back into fiber or copper and connected to the